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Strategies for the Compliance: Contemporary Approaches to Equipment Qualification of Safety Related Systems for New Build Nuclear Facilities

Strategie zgodności: współczesne podejścia do kwalifikacji sprzętu przeznaczonego dla systemów związanych z bezpieczeństwem dla nowo budowanych obiektów jądrowych

This article addresses modern strategies for equipment qualification (EQ) in safety-related systems within nuclear facilities, focusing on ensuring reliability under harsh conditions, including seismic events, extreme temperatures, and radiation exposure. Equipment qualification is crucial in industries where failure could lead to catastrophic consequences. Contemporary approaches emphasize a risk-informed methodology, leveraging advanced simulation tools, modular design, continuous monitoring, and life-cycle-based qualification to optimize both safety and efficiency. Compliance with international standards, enhanced documentation, and robust supply chain management are critical for meeting regulatory requirements and ensuring long-term reliability. By adopting digital innovations, collaborative frameworks, and resilient design principles, nuclear facilities can better align with evolving safety standards while ensuring the functionality and safety of equipment in critical systems.

Keywords: Equipment Qualification (EQ), Safety-Related Systems, Seismic Qualification, Electromagnetic Compatibility (EMC), Risk-Informed Approach, Probabilistic Risk Assessment (PRA), Aging Management Programs (AMP), International Atomic Energy Agency (IAEA), Continuous Monitoring, Life-Cycle-Based Qualification, Configuration Management (CM), Supply Chain Management

W artykule omówiono nowoczesne strategie kwalifikacji wyposażenia dla systemów związanych z bezpieczeństwem w obiektach jądrowych, koncentrując się na zapewnieniu niezawodności w trudnych warunkach, w tym w przypadku zdarzeń sejsmicznych, ekstremalnych temperatur i narażenia na promieniowanie. Kwalifikacja sprzętu ma kluczowe znaczenie w branżach, w których awaria może prowadzić do katastrofalnych skutków. Współczesne podejścia kładą nacisk na metodologię uwzględniającą ryzyko, wykorzystując zaawansowane narzędzia symulacyjne, modułową konstrukcję, ciągły monitoring i kwalifikację opartą na cyklu życia w celu optymalizacji zarówno bezpieczeństwa, jak i wydajności. Zgodność z normami międzynarodowymi, ulepszona dokumentacja i solidne zarządzanie łańcuchem dostaw mają kluczowe znaczenie dla spełnienia wymogów regulacyjnych i zapewnienia długoterminowej niezawodności. Dzięki przyjęciu innowacji cyfrowych, ram współpracy i odpornych zasad projektowania obiekty jądrowe mogą lepiej dostosować się do zmieniających się norm bezpieczeństwa, zapewniając jednocześnie funkcjonalność i bezpieczeństwo swego wyposażenia w systemach krytycznych.

Słowa kluczowe: kwalifikacja sprzętu (EQ), systemy związane z bezpieczeństwem, kwalifikacja sejsmiczna, kompatybilność elektromagnetyczna (EMC), podejście uwzględniające ryzyko, ocena ryzyka probabilistycznego (PRA), programy zarządzania starzeniem (AMP), Międzynarodowa Agencja Energii Atomowej (IAEA), ciągły monitoring, kwalifikacja oparta na cyklu życia, zarządzanie konfiguracją (CM), zarządzanie łańcuchem dostaw

Introduction

Equipment qualification for safety-related systems is a critical process in industries like nuclear power, aerospace, and defense, where equipment failure could have severe consequences. It involves a series of tests, analyses, and evaluations to ensure that equipment will perform its required safety functions under specified conditions. These conditions may include normal operation, as well as accident or emergency situations like earthquakes, fires, floods, or radiation exposure. Proper equipment qualification ensures that safety-related systems will operate reliably in normal and adverse conditions, thereby preventing accidents and protecting public safety and environment against radioactive or toxic releases and excessive aftermaths. This is particularly vital in industries where equipment failure could lead to catastrophic consequences.

Principal aspects of Equipment Qualification, particularly of electrical, electronic and programmable electronic (E/E/PE) equipment components, covering following:

- Environmental Qualification (EQ), ensures that equipment can withstand environmental conditions such as temperature, humidity, radiation, seismic events, and other factors. Testing includes exposure to simulated environmental conditions to verify that the equipment will perform its intended function when required. In general, the equipment test sample shall survive whole sequence of simulated environmental conditions and extreme event effects to prove its suitability for whole mission time – so called Qualified Life.
- Seismic Qualification (SQ), which involves demonstrating that equipment can function properly during and after seismic events. Equipment is subjected to simulated earthquake conditions to ensure it can survive and operate correctly during an actual seismic event.
- Electromagnetic Susceptibility / Electromagnetic Compatibility (EMC), where equipment items must not be affected by electromagnetic/radio-frequency interference (EMI/RFI) and should not produce EMI that could affect other equipment. Testing ensures that the equipment can operate reliably in its electromagnetic environment, but also set-up

proper installation EM environment conditions to attain reasonable levels of the EM Compatibility for severity zonation in the nuclear facility.

Other key aspects present:

- Aging and Wearing; there an equipment must be qualified to perform over its expected lifespan, considering factors like material degradation, corrosion, fatigue, and other aging effects. Accelerated aging tests may be conducted to simulate long-term use and/or time frames between surveillance checks or replacements either critical equipment parts or equipment component itself.

Equipment to be qualified, shall be properly Functional Testing within the process, and verifies that the equipment can perform its required safety functions upon and after simulated service condition. Functional tests and functional checks are conducted under both normal and adverse conditions to ensure reliability under adverse or severe simulated conditions.

Equipment qualification process heavily lies on Documentation and Traceability. Detailed documentation is required to demonstrate compliance with the qualification requirements. This includes test reports, analysis results, and quality assurance records. Well-structured documentation and interfaces within a train of EQ process guarantees compliance with license basis, limited deviances and precluding resource demanding clashes. Typical steps in Equipment Qualification Process are as following:

- Define Requirements: Determine the specific safety functions the equipment must perform, as well as the environmental and operational conditions it must withstand.
- Select and Prepare Equipment: Identify the equipment to be qualified and prepare it for testing.
- Conduct Qualification Testing: Perform the necessary environmental, seismic, EMI/EMC, and functional tests. Use appropriate standards and guidelines, such as those from the IEEE, IEC, or ASME.
- Analyze Test Results: Evaluate the test data to confirm that the equipment meets the qualification criteria.
- Document Results: Create comprehensive documentation that includes test plans, procedures, results, and conclusions, ensuring traceability and compliance with regulatory requirements.
- Review and Approval: Obtain approval from relevant authorities, such as regulatory bodies, ensuring that all safety-related equipment is qualified for its intended use.

Seismic fragility testing of a newly developed modular I&C (Instrumentation and Control) cabinet for next-generation nuclear power plants. The cabinet failed during a simulation of an earthquake with a magnitude corresponding to a 100,000-year recurrence interval (by courtesy of Rizzo Associates Czech)

Key Strategies of EQ Process for New Builds

Equipment qualification (EQ) in nuclear facilities, particularly electric (or E/E/PE items) applied for safety-related systems, is crucial for ensuring that equipment can perform reliably under normal, abnormal, and accident conditions. Given the evolving regulatory environment and advancements in technology, contemporary approaches to EQ in new build nuclear facilities emphasize compliance with safety codes and standards while incorporating innovative practices. Here are ten key strategies.

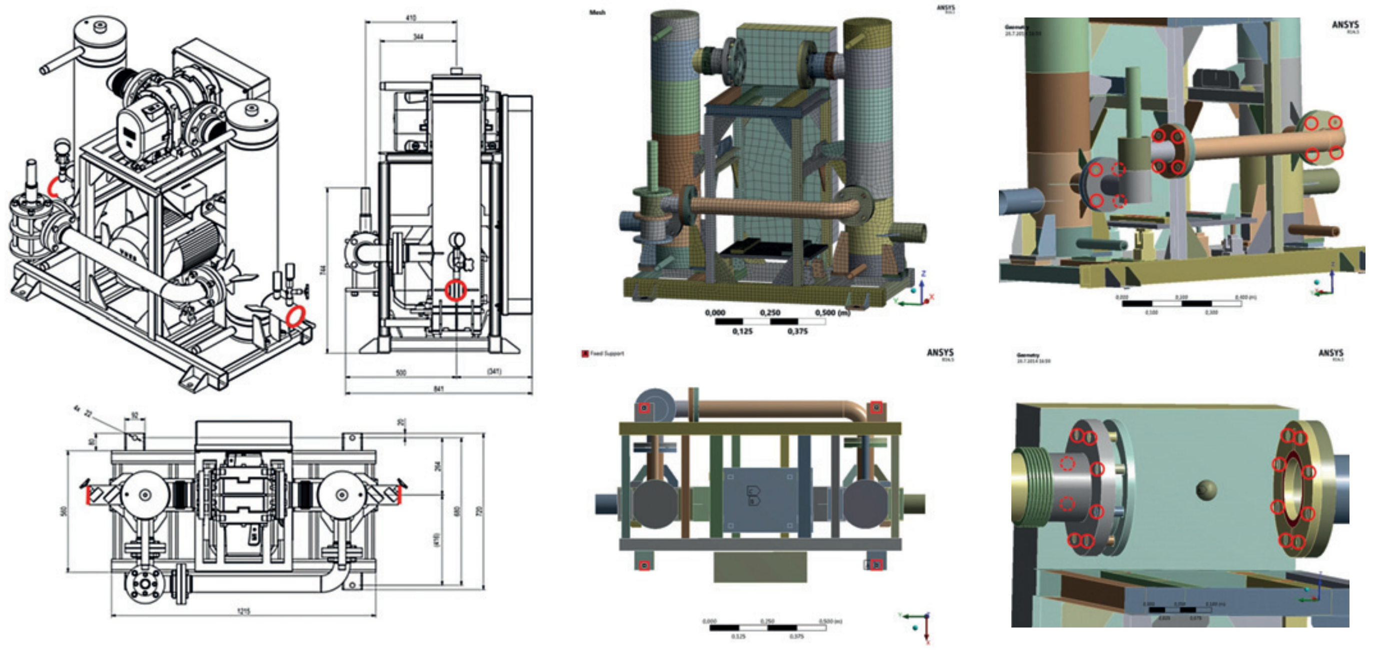
1. Risk-Informed Approach to Qualification

In the realm of safety-critical systems, effective resource allocation and rigorous testing are paramount. One approach to achieving this balance is through prioritization based on risk. By focusing on qualifying equipment according to its significance to safety, organizations can ensure that higher-risk components undergo more thorough testing and analysis. This strategy allows for the efficient allocation of resources while maintaining stringent safety standards. The use of various classification systems, such as Safety Class, Seismic Class, Environmental Class, and Electromagnetic Compatibility (EMC) Levels, enables a deterministic approach to risk prioritization.

Additionally, integrating Probabilistic Risk Assessments (PRA) into the qualification process further enhances efficiency and effectiveness. PRA is instrumental in identifying critical components that necessitate rigorous qualification processes, thus minimizing unnecessary testing on non-critical equipment. This approach not only refines the demands for proving equipment reliability but also supports the approval and utilization of commercial-grade equipment within safety systems. Furthermore, the consideration of Design Extended Conditions within plant states adds an additional layer of safety by ensuring that systems remain robust under a variety of scenarios.

2. Use of Advanced Simulation and Modeling Tools

Implementing digital twins of equipment allows engineers to simulate operational conditions and stressors with high precision. This approach enables virtual testing and optimization before physical qualification tests are conducted,



Digital twin of Air-Compressor Unit to be qualified for safety-related systems. Example of the parametrization of essential design features and caveats (inclusion / exclusion criteria of inherent capacity) to an application for the information modeling purpose (by courtesy of Rizzo Associates Czech)

significantly enhancing the efficiency of the engineering process. Properly integrating digital twin modeling into the equipment qualification (EQ) process provides a powerful tool for managing data, documenting procedures, and ensuring the traceability of critical information throughout the design, installation, maintenance, and licensing stages.

Similarly, Finite Element Analysis (FEA) is a valuable method for predicting how equipment will respond to various stressors, such as temperature changes, seismic events, and other challenging conditions. By using FEA, engineers can accurately forecast equipment behavior, reducing the need for extensive physical testing and allowing for a more streamlined development process.

Thermal-hydraulic and radiation source modeling is also essential for predicting the thermal and fluid dynamics in safety systems, or radiation exposure rates and vectors of acting. This detailed simulation ensures that equipment can withstand expected operational extremes, safeguarding the integrity and reliability of the entire system. Incorporating these advanced simulation techniques not only improves the qualification process and predictions of behavior of applied constructional materials but also enhances the overall safety and performance of critical equipment if considering protective barrier or diminished measures.

3. Adopting Modular and Standardized Design Approaches

Incorporating pre-qualified, standardized modules and components in new nuclear builds significantly reduces both time and cost associated with equipment qualification (EQ). These modules, having already undergone rigorous testing and certification for nuclear safety, eliminate the need for repetitive assessments, thereby accelerating the development process.

Additionally, the establishment of modular testing facilities that can be easily reconfigured for various equipment or conditions further enhances the efficiency of the qualification process. These adaptable setups offer increased flexibility, allowing for more streamlined testing procedures tailored to specific requirements, ultimately improving the overall speed and cost-effectiveness of nuclear safety evaluations.

Those provisions can help not only cost-effective managed EQ process but enhance a multicollaboration on international projects and expand potentials for prolongation of qualification lifetime and ageing management on operational facilities.

4. Continuous Monitoring and Real-Time Data Collection

Integrating embedded sensors into safety-critical systems is revolutionizing how we monitor and maintain equipment. These sensors continuously track key parameters such as temperature, pressure, and vibrations, providing real-time data that offers valuable insights into the current performance of the machinery. This constant stream of information enables the early detection of potential issues, helping to prevent equipment failures before they occur. Typical example is using LIRA (Line Resonance Analysis) technique to evaluate cable performance that monitors cable condition overall cable health as well as locally degraded areas.

In conjunction with this technology, condition-based qualification is emerging as a more accurate method of evaluating equipment. By relying on real-time monitoring data, this approach allows for the qualification of equipment based on its actual operating conditions, rather than on hypothetical worst-case scenarios that may not be relevant. This shift not only ensures a higher level of safety but also optimizes the performance and longevity of the equipment.

5. <u>Life-Cycle-Based Qualification Process</u>

Maintaining compliance and safety in critical equipment requires more than a one-time qualification process. A proactive approach involves continuous or periodic requalification throughout the entire equipment life-cycle. By doing so, organizations can ensure that their equipment remains in line with evolving safety standards and operational requirements. This ongoing requalification process helps to identify potential issues before they become significant problems, thereby safeguarding both personnel and operations.

In addition to life-cycle qualification, the implementation of Aging Management Programs (AMPs) is crucial. These programs are designed to monitor and manage the aging of safety-related equipment. AMPs typically involve regular testing, material analysis, and, when necessary, the refurbishment or replacement of components. By actively managing the aging process, organizations can extend the useful life of their equipment while maintaining high safety standards.

Another critical aspect of equipment safety is Configuration Management (CM). CM ensures that the equipment's design, documentation, and operational parameters are accurately maintained throughout its life-cycle and keep as-design state equal to as-built. This process involves keeping detailed records of all changes made to the equipment, whether they are physical modifications, software updates, or procedural adjustments. By rigorously managing configuration, organizations can prevent discrepancies between the current state of the equipment and its documented design, reducing the risk of operational errors or safety breaches. When combined with continuous qualification and aging management, effective configuration management creates a robust framework that supports the long-term safety, reliability, and compliance of critical equipment.

6. <u>Regulatory Harmonization and Collaboration</u>

To achieve excellence in nuclear operations, it is essential to align with recognized international standards. Organizations like the International Atomic Energy Agency (IAEA), the International Electrotechnical Commission (IEC), the Institute of Electrical and Electronics Engineers (IEEE), and the American Society of Mechanical Engineers (ASME), and others, set the global benchmarks for safety, efficiency, and best practices. Adopting these standards ensures that nuclear facilities operate at the highest levels of compliance and safety worldwide, and further outlined basis for application specific codes and other industrial standards

Equally important is fostering strong collaboration with regulatory authorities. By engaging with nuclear regulatory bodies early in the process and maintaining ongoing communication, operators can ensure that their qualification procedures remain transparent, fully compliant, and responsive to evolving regulations. This proactive approach not only mitigates risks but also promotes trust and accountability in the nuclear industry. Therefore, proper and in-depth documentation and traceability of the overall EQ process aspects is fundamental and highly demanded.

7. <u>Enhanced Documentation and Traceability</u>

A robust documentation system is essential to the Equipment Qualification (EQ) process, ensuring that every step, from testing procedures to final results and any deviations, is meticulously recorded. This comprehensive documentation should be preserved throughout the entire lifespan of the equipment, providing a reliable reference for future assessments.

To streamline this process, the application of an integral Content Management System (iCMS) is highly beneficial. A well-implemented CMS can centralize all EQ documentation, making it easily accessible, searchable, and manageable, across stakeholders and involved parties. It ensures consistency in the way information is recorded and maintained, reducing the risk of errors and omissions while enabling more efficient document control across all stages of the equipment lifecycle.

Equally important is the implementation of traceability systems. These systems should monitor the history, testing, and any modifications made to safety-critical components. By integrating traceability systems with a CMS, organizations can ensure that all relevant data is automatically linked to specific components, enabling quick access to historical information and facilitating efficient verification. This integration not only enhances the ability to conduct compliance audits but also promotes overall equipment reliability and safety by ensuring that all modifications and tests are properly tracked and documented.

8. <u>Adoption of a Robust Supply Chain Management</u>

In the nuclear industry, ensuring the reliability of suppliers, particularly those providing critical components, is of paramount importance. One key aspect of this is a robust supplier qualification process. Suppliers must have well-established procedures in place to ensure that the parts and materials they provide meet the stringent requirements of nuclear safety. To maintain these high standards, regular audits are conducted to verify that suppliers remain compliant with all relevant nuclear safety protocols.

Equally essential is the implementation of comprehensive quality assurance programs – preferred QMS are accredited programs according to ISO 19443 (international) or ASME NQA-1 (compliance of 10CFR50, Appendix B). These programs must extend across every level of the supply chain, ensuring that all components meet rigorous standards before being introduced into safety-critical systems. By proactively identifying and preventing substandard components from entering the system, these quality assurance measures are vital in upholding the safety and integrity of nuclear operations.

9. <u>Human Factors Engineering (HFE)</u>

Ensuring that operators and maintenance personnel are properly trained in the specific requirements and procedures for qualified equipment is critical. To achieve this, it is essential to utilize advanced educational tools that cater to diverse learning styles, including digital simulations, interactive modules, and hands-on workshops. The development of a scalable knowledge base is equally important, providing accessible and up-to-date resources that can be tailored to different levels of expertise. Collaboration with universities and academic institutions further strengthens this approach by integrating cutting-edge research, theories, and methodologies into the training programs. By fostering a continuous learning environment, this partnership helps ensure that personnel are equipped with the latest skills and knowledge, setting a foundation for long-term competence and safety in the workplace.

Additionally, incorporating ergonomic design into equipment interfaces and control systems is vital. By prioritizing ease of use and reducing complexity, these designs help to minimize the potential for human error during both operation and maintenance, contributing to a safer and more efficient working environment.

10. <u>Incorporation of Resilience and Redundancy</u>

Redundant systems involve the intentional duplication of critical components or functions within a system to enhance its reliability and safety. The primary goal is to ensure that if one component fails, others can seamlessly take over its function without causing the entire system to fail, thus ensuring uninterrupted operation or a safe shutdown. This approach is particularly crucial in fields where failure could lead to catastrophic consequences, such as aviation, power plants, and medical devices.

Different forms of redundancy are employed to achieve this level of reliability. Hardware redundancy involves using multiple copies of hardware components, such as processors, sensors, or power supplies, so that if one fails, the system can switch to a backup. In software redundancy, different versions of software or algorithms are used in parallel, providing a fallback if one version encounters a problem. Information redundancy uses encoded data with additional information, such as parity bits or error-correcting codes, to detect and correct errors. Functional redundancy means incorporating multiple ways of performing the same task, allowing the system to continue operating even if one function fails.

In safety-critical systems, redundancy plays a vital role in ensuring that the system can either continue functioning despite failures or fail in a safe and controlled manner. The goal is to meet fail-operational and fail-safe requirements, critical to maintaining safety in complex environments.

Resilient design focuses on ensuring that systems can not only withstand normal conditions but also unexpected events such as natural disasters, cyberattacks, or human error. The objective is to design systems that can continue functioning or fail in a controlled manner without causing harm to people, the environment, or critical infrastructure.

This approach includes several key principles. Fail-safe design ensures that the system defaults to a safe state in the event of a failure, such as a nuclear reactor shutting down automatically if something goes wrong. Graceful degradation allows the system to maintain a reduced level of functionality during a failure, rather than completely shutting down, ensuring that essential operations can continue. Self-healing systems are designed to detect and correct failures automatically, as seen in smart grids or autonomous networks. Adaptability allows the system to adjust its operations based on changing conditions, learning from past failures and anticipating future risks. Finally, modular design makes it possible to isolate and replace components without affecting the entire system, enabling quick repairs and upgrades.

By integrating redundant systems and resilient design principles, we can create robust and safe systems that manage risks effectively in critical environments. These designs not only help prevent failures but also mitigate the consequences when failures do occur.

Conclusion

This article discusses modern approaches and strategies for ensuring compliance with safety-related systems in newly constructed nuclear facilities. The focus is on equipment qualification (EQ), a critical aspect of ensuring that safety-related equipment can perform under harsh conditions typical in nuclear environments, such as seismic events, extreme temperatures, and radiation.

Key strategies outlined include.

1. Risk-Based Approaches: Emphasizing a risk-based perspective to prioritize EQ efforts based on the likelihood and impact of failure. This helps optimize resource allocation for systems where safety is paramount.
2. International Standards Compliance: Highlighting the importance of aligning EQ processes with international safety standards, such as those set by the International Atomic Energy Agency (IAEA), to ensure harmonization across global nuclear projects.
3. Lifecycle Management: Stressing the importance of considering EQ throughout the entire lifecycle of the equipment, from design and manufacturing to operation and decommissioning, ensuring continuous compliance with safety requirements.
4. Digital and Technological Innovations: Utilizing advanced digital tools and simulations to streamline EQ processes, reduce testing times, and enhance accuracy in predicting equipment performance under stress conditions.
5. Collaboration and Knowledge Sharing: Encouraging collaboration among industry stakeholders, regulatory bodies, and international organizations to share best practices, lessons learned, and technological advancements in EQ.

These strategies help address the evolving challenges of nuclear safety in new builds, ensuring that equipment qualification processes are more efficient, standardized, and capable of meeting stringent safety requirements.

Further details are also available in the List of References.

LIST OF REFERENCES

Requirements relevant to equipment qualification in nuclear installations are established in the following publications:

- IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), “Safety of Nuclear Power Plants: Design”;
- IAEA Safety Standards Series No. SSR-2/2 (Rev. 1), “Safety of Nuclear Power Plants: Commissioning and Operation”;
- IAEA Safety Standards Series No. SSR-3, “Safety of Research Reactors”;
- IAEA Safety Standards Series No. SSR-4, “Safety of Nuclear Fuel Cycle Facilities”.

Several other IAEA safety standards also have some relevance to equipment qualification. These include the following:

- IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), “Safety Assessment for Facilities and Activities”;

- IAEA Safety Standards Series No. GSR Part 2, "Leadership and Management for Safety", and its supporting Safety Guides, IAEA Safety Standards Series No. GS-G-3.1, "Application of the Management System for Facilities and Activities", and No. GS-G-3.5, "The Management System for Nuclear Installations".
- IAEA Safety Standards Series No. SSG-30, "Safety Classification of Structures, Systems and Components in Nuclear Power Plants";
- IAEA Safety Standards Series No. SSG-34, "Design of Electrical Power Systems for Nuclear Power Plants";
- IAEA Safety Standards Series No. SSG-39, "Design of Instrumentation and Control Systems for Nuclear Power Plants";
- IAEA Safety Standards Series No. SSG-48, "Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants".

List of the IEC and IEEE standards that relate directly to the recommendations provided in the IAEA Safety Standards and Guides. The presented list is not intended to provide completed standards references framework, but it identifies the entrance into the sets of IEC and IEEE, or ASME standards.

NOTE: Dates of issues of standards are intentionally omitted because either evolved or latest versions are not endorsed by regulatory bodies.

IEC 60515,	"Nuclear power plants — Instrumentation Important to Safety — Radiation Detectors — Characteristics and Test Methods"
IEC 60772,	"Nuclear Power Plants — Instrumentation Systems Important to Safety — Electrical Penetration Assemblies in Containment Structures"
IEC/IEEE 60980-344,	"Nuclear Facilities — Equipment Important to Safety — Seismic Qualification
IEC 61513,	"Nuclear Power Plants — Instrumentation and Control Important to Safety — General Requirements for Systems"
IEC 62003,	"Nuclear Power Plants — Instrumentation, Control and Electrical Power Systems — Requirements for Electromagnetic Compatibility Testing"
IEC 62342,	"Nuclear Power Plants — Instrumentation and Control Systems Important to Safety — Management of Ageing"
IEC TR 61000-4-1,	"Electromagnetic Compatibility (EMC) — Part 4-1: Testing and Measurement Techniques — Overview of the IEC 61000-4 Series"
IEC 61000-6-1,	"Electromagnetic Compatibility (EMC) — Part 6-1: Generic Standards — Immunity Standard for Residential, Commercial and Light-Industrial Environments"
IEC/IEEE 60780-323,	"Nuclear Facilities — Electrical Equipment Important to Safety — Qualification"
IEEE Std 308,	"IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations"
IEEE Std 334,	"IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations"
IEEE Std 382,	"IEEE Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations and Other Nuclear Facilities"
IEEE Std 383,	"IEEE Standard for Qualifying Electric Cables and Splices for Nuclear Facilities"
IEEE Std 420,	"IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations"
IEEE Std 535,	"IEEE Standard for Qualification of Class 1E Vented Lead Acid Storage Batteries for Nuclear Power Generating Stations"
IEEE Std 572,	"IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations and Other Nuclear Facilities"
IEEE Std 603,	"IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations"
IEEE Std 627,	"IEEE Standard for Qualification of Equipment Used in Nuclear Facilities"
IEEE Std 649,	"IEEE Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations"
IEEE Std 1205,	"IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Electrical Equipment Used in Nuclear Power Generating Stations and Other Nuclear Facilities"
IEEE Std 1682,	"IEEE Standard for Qualifying Fiber Optic Cables, Connections, and Optical Fiber Splices for Use in Safety Systems in Nuclear Power Generating Stations"
ASME QME-1,	"Qualification of Active Mechanical Equipment Used in Nuclear Facilities"

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Ministerstwo Przemysłu

polskiatom

IGEOS nuclear